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SEARCH FOR A HIGGS BOSON DECAYING INTO TWO PHOTONS WITH THE L3 DETECTOR AT LEP

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A search is performed for a Higgs boson, decaying into two photons, using the L3 data collected at centre of mass energies between $\sqrt{s} = 189$ and 202 GeV, corresponding to an integrated luminosity of 400 pb^{-1}. The processes $e^+e^- \rightarrow \mathrm{Zh} \rightarrow \mathrm{q\bar{q}}\gamma\gamma$, $e^+e^- \rightarrow \mathrm{Zh} \rightarrow \nu\bar{\nu}\gamma\gamma$, $e^+e^- \rightarrow \mathrm{Zh} \rightarrow \ell^+\ell^-\gamma\gamma$ are considered. The observed data are found to be consistent with the expected background from standard physics processes. Limits on the branching fraction of the Higgs boson decay into two photons as a function of the Higgs mass are shown and a lower mass limit on a fermiophobic Higgs is derived.

The Standard Model (SM) has been tested to a very good accuracy at LEP, SLC, the Tevatron and at HERA. However, in spite of its great success, the mechanism to generate the particle masses has not been verified experimentally. In the Standard Model the vector bosons and fermion masses are generated through their interactions with the Higgs field which should manifest itself as a neutral spin-0 boson, the Higgs boson. No direct observation of a Higgs boson has been made yet and current direct searches constraint its mass to $M_{\mathrm{h}} > 113$ GeV [1] in the minimal SM. Here we investigate models with extended Higgs sectors. In this contribution we report on the search for a Higgs boson produced in association with a Z boson through the process $\mathrm{e^+e^-} \rightarrow$Zh, followed by the decay h$\rightarrow \gamma\gamma$, in all decay modes of the Z boson. In the Standard Model, the decay of a Higgs boson h into a photon pair occurs via a quark- or W-boson loop and its branching fraction is small. However, several extended models predict enhancements of this branching fraction. In Two Higgs Doublet Models of Type I [2], with an appropriate choice of the model parameters, the lightest CP even Higgs boson does not couple to fermions at tree level. Such a Higgs is expected to decay dominantly into a pair of photons if its mass is below 90 GeV.

The data were collected with the L3 detector at a centre-of-mass energy between $\sqrt{s} = 189$ and 202 GeV and amount to an integrated luminosity of about 400 pb^{-1}. A cut-based selection is performed in order to select events with photons and to identify the Z in its various decay modes. This gives rise to $\mathrm{q\bar{q}}\gamma\gamma$, $\nu\bar{\nu}\gamma\gamma$ and $\ell^+\ell^-\gamma\gamma$ final states, with $\ell = \mathrm{e},\mu,\tau$. The selection criteria for each final state rely on a common photon identification and will be briefly summarised in the following. The interested reader should consult Ref. [3] for more details.

Table 1. Number of events expected from Standard Model processes compared to the observed number of events, together with the signal efficiency for a hypothetical Higgs boson of 95 GeV mass.

	$\sqrt{s} = 189$ GeV, $L_{int} = 176$ pb^{-1}			$\sqrt{s} = 192 - 202$ GeV, $L_{int} = 233$ pb^{-1}		
Final State	Data	Bkgd. predicted	Efficiency	Data	Bkgd. predicted	Efficiency
$q\bar{q}\gamma\gamma$	10	16.2	43%	14	12.6	45%
$\nu\bar{\nu}\gamma\gamma$	3	4.3	29%	-	-	-
$\ell^+\ell^-\gamma\gamma$	5	2.5	37%	-	-	-

Photons are identified as clusters in the electromagnetic calorimeter with a shower shape compatible with that of an electromagnetic shower and which are not associated with a charged track. To suppress photons from initial state radiation, the most serious background for this search, only photons in the polar angle ranges $45^\circ < \theta < 135^\circ$, $25^\circ < \theta < 35^\circ$ or $145^\circ < \theta < 155^\circ$ are accepted. To ensure that the pair of photons arise from the decay of a heavy resonance we require the energy of the most energetic photon to be larger than 10 GeV and the energy of the second most energetic photon to be larger than 6 GeV.

The signature for the $q\bar{q}\gamma\gamma$ final state is a pair of isolated photons accompanied by two jets. To select these events we apply a hadronic preselection requiring high multiplicity events with large visible energy in the detector. Furthermore, only those events which contain at least two photons are selected. The recoil mass against the di-photon system must be consistent with the Z mass, $|M_{\mathrm{recoil}} - M_{\mathrm{Z}}| < 15$ GeV.

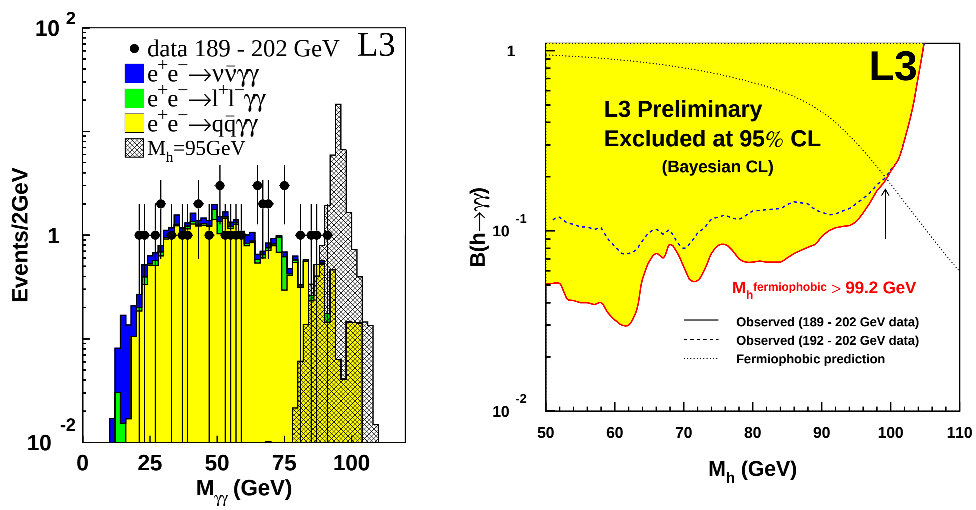
The $\nu\bar{\nu}\gamma\gamma$ final state is characterised by the presence of two photons and missing energy in the event. To reduce the background from the $e^+e^- \rightarrow \gamma\gamma(\gamma)$ process and from double radiative events with final state particles escaping detection, we require photon acoplanarity and a total transverse momentum of the di-photon system greater than 3 GeV. The missing mass must be consistent with the Z boson mass within ± 10 GeV.

The $\ell^+\ell^-\gamma\gamma$ final state is characterised by the presence of two photons and a pair of same type leptons in the event. We require the recoil mass against the di-photon system to be consistent with the Z mass, $|M_{\mathrm{recoil}} - M_{\mathrm{Z}}| < 15$ GeV.

The number of data and expected background events left after the selection is applied, as well as the signal efficiency in each of the studied channels, are reported in Table 1.

Since no signal is observed in the data, we evaluate the confidence level for the absence of a Higgs signal using the reconstructed di-photon invariant mass as a final discriminant variable. This distribution is shown in Figure 1(a) for all Z final states combined.

The calculation of the limits takes into account systematic uncertainties of 1% from the signal Monte Carlo statistics, 1.5% from the simulation of the photon isolation criteria and 4% on the number of expected background events. Figure 1(b) shows the measured upper limits on the branching fraction B(h$\rightarrow \gamma\gamma$) as a function of the Higgs mass assuming the Standard Model rate for the Zh production. The theoretical prediction is also shown for a fermiophobic Higgs boson as calculated



(a) (b)

Fig. 1. (a) The distribution of the reconstructed di-photon invariant mass for all Z final states combined, after the final selection, in data, background and for a Higgs boson signal with the mass $M_{\mathrm{h}} = 95$ GeV. The signal, assuming the Standard Model cross section and a branching fraction $\mathrm{B}(\mathrm{h} \to \gamma\gamma) = 1$, is superimposed and normalised to the integrated luminosity. (b) Excluded values of the branching fraction $\mathrm{B}(\mathrm{h} \to \gamma\gamma)$ as a function of the Higgs mass, in the assumption of a Standard Model production cross section. The theoretical prediction is also presented.

with the HDECAY program [4]. The lower limit on the mass of a fermiophobic Higgs boson is set at $M_{\mathrm{h}} > 99.2$ GeV at 95% confidence level. The LEP Higgs Working Group has combined the data up to $\sqrt{s} = 209$ GeV from the four experiments and obtained a lower mass limit of 106.4 GeV at 95% confidence level [1].

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